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Developments in the acquisition of spatial data from imagery

Submitted by the International Society for Photogrammetry and Remote Sensing**

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DEVELOPMENTS IN THE ACQUISITION OF SPATIAL DATA FROM IMAGERY

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SUMMARY

The International Society for Photogrammetry and Remote Sensing (ISPRS) is a non-governmental international organization, devoted to the development of international cooperation for the advancement of knowledge, research, development, education and training in the photogrammetry, remote sensing and spatial information sciences, their integration and applications, to contribute to the well-being of humanity and the sustainability of the environment.

ISPRS covers a broad range of topics dealing with the acquisition and processing of data from a variety of imaging systems for topographic mapping and data collection for Geographic Information Systems (GIS), and environmental mapping and monitoring. ISPRS has seen significant new trends in the development of technologies and methods for mapping. New technologies available for mapping and data collection for Geographic Information Systems (GIS) include new sources of digital image data from space and aircraft, as well as technologies for information extraction.

Space-borne image data acquisition includes a choice from the range of satellite image data, based on the resolution of the data. Resolution is usually defined in terms of spatial, spectral and temporal resolutions. Spatial resolution refers to the footprint of the data on the ground, usually expressed as meters. Spectral resolution refers to the extent of wavelengths that are discriminated by the sensor. Temporal resolution refers to the repeat cycle of the data acquisition, that is the time between consecutive satellite passes over the same area.

For mapping high spatial resolution image is the preferred choice, since it is required for the identification of details in the image required for mapping. Airborne systems available for data collection for mapping include film based systems and new digital camera systems. The film based systems are the currently available technologies, but new digital systems are being developed to replace film systems. In addition, new terrain laser scanners provide a rapid system for derivation of terrain elevations.

Output from mapping systems are now digital, either as line maps or orthophotos. With the increasing introduction of digital photogrammetric mapping systems, orthophotos are becoming a more commonly requested map product. The digital orthophoto has the advantage that it can be overlaid on digital GIS data.

These new technologies have the advantages that they will lead to more rapid data collection, but also new levels of technology transfer and personnel training will be required for developing countries to be able to tale advantage of them.

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INTRODUCTION

The International Society for Photogrammetry and Remote Sensing (ISPRS) is a non-governmental international organization, devoted to the development of international cooperation for the advancement of knowledge, research, development, education and training in the photogrammetry, remote sensing and spatial information sciences, their integration and applications, to contribute to the well-being of humanity and the sustainability of the environment.

Photogrammetry and Remote Sensing are defined as the art, science, and technology of obtaining reliable information from non-contact imaging and other sensor systems about the Earth and its environment, and other physical objects and processes through recording, measuring, analyzing and representation.

Spatial Information Science is the art, science, and technology of obtaining reliable spatial, spectral and temporal relationships between physical objects, and of processes for integration with other data for analysis, portrayal and representation, independently of scale.

ISPRS covers a broad range of topics dealing with the acquisition and processing of data from a variety of imaging systems for topographic mapping and data collection for Geographic Information Systems (GIS), and environmental mapping and monitoring. ISPRS has seen significant new trends in the development of technologies and methods for mapping. Output products from mapping systems are usually digital, thus enabling the processing of the data in GIS or similar digital mapping software. There is an increased level of automation in information extraction, especially for terrain elevation data and the derivation of digital orthophotos. The use of orthophotos has increased as a product for the mapping, replacing line mapping in many cases. There is a much broader range of image data now available for mapping purposes, especially the new series of satellite systems, and there will be further such systems developed in the future. In addition, the use of the data is much broader than for only topographic mapping. Preservation of the environment

and supporting the sustainability of development are important applications of the digital data collected by members of ISPRS. Indeed, the sustainability of development is becoming a critical issue for application of image data, but ISPRS members are still to learn a great deal about how the technologies will be used for supporting sustainable development. This is an important issue for the future and should also be addressed by the UN.

This paper will summarize, under the topic of 'Spatial Data Collection Issues', the data available for mapping and the technologies use for production of digital map data.

CHOICE OF IMAGE DATA

Satellite Data

The choice of the most suitable image data from which to derive mapping and GIS will be a function of the applications of the map data. Because one set of image data cannot satisfy the production of all types of map products, the initial decision on choice of data must be based on the required resolution of the output product. Resolution is usually defined in terms of spatial, spectral and temporal resolutions. Spatial resolution refers to the footprint of the data on the ground, usually expressed in meters. Spectral resolution refers to the extent of wavelengths that are discriminated by the sensor. These systems may vary between broad ranges of the spectrum, as has been the case with most so-called 'multi-spectral' sensors, to very narrow bands of the spectrum, as is currently the case with the 'hyperspectral' systems. Temporal resolution refers to the repeat cycle of the data acquisition, that is the time between consecutive satellite passes over the same area.

- *High spatial resolution data*, better than 30 meters, usually involves large volumes of data taken with low repeat cycles, of the order of 20-30 days, as is the case with the remote sensing satellite, such as Landsat, SPOT etc. This poor repeat cycle can largely been overcome by providing pointing capability in the satellite, as is he case with recently launched satellites. In this case the repeat cycle will be as little as a few days, subject to weather conditions.

- *High spectral resolution data* will normally be acquired on low repeat cycles and comprise multi-spectral data ranging from a small numbers of bands to many hundreds as is the case of hyperspectral systems. Hyperspectral data sensing has opened up new areas of applications, which would enhance the use of remote sensing data, such as the discrimination of different

vegetation species, mineral types, diseases etc. It is therefore particularly useful for environmental mapping. However, for multi-spectral data, the repeat cycle will become an issue if changes in disease patterns of crop growth patterns occur more frequently than the repeat cycle.

- *High temporal data* is collected at very regular intervals, eg several times per day, as is the case with the NOAA satellites, but with low spatial resolutions of 1 to 4 km.

For mapping applications, the high spatial resolution data is chosen, since it is required for the identification of details in the image required for mapping. For high spatial resolution data, the repeat cycle is not usually an important issue unless there are rapid changes in details on the terrain surface.

Developments in low cost satellite systems, so-called micro-satellites, by a range of countries have enabled countries that do not have the funding or technologies to launch their own satellite systems to enter the space industry. Typical of these are the systems that have been launched by Surrey University in the UK, and others. The type of sensor that is launched by a country should be designed to suit the applications of that country and not simply to replicate systems being launched by other countries. Therefore, the decision to develop any satellite system should be based thorough investigations of the needs of the country and resources available to undertake such a project.

High Spatial Resolution Satellite Systems.

The applications of satellite data for mapping and GIS have so far been limited to small and medium scale mapping, usually for smaller scales than 1:25,000. However, the authorization for commercial ownership and operation of satellites giving 1 meter data has stimulated a number of companies to develop high-resolution earth observation systems. The first of these, IKONOS II launched by Space Imaging Corporation, which has been successfully operating for more than one year, is the beginning of a new era of satellite imagery wherein spatial resolutions match the resolutions of aerial photographic data. It includes a flexible imaging system for the acquisition of 1 meter resolution stereo-data, and 4 meter multi-spectral data. The suitability of this data for mapping is still being tested, but some initial tests indicate that the geometric accuracies of this data are beyond initial expectations. The applications of the multi-spectral data have not been fully explored, but it will clearly be of advantage for automatic procedures of information extraction. Company estimates are

that the imagery will be suitable for image mapping at scales larger than 1:10,000, indeed up to 1:2,400. However, this industry is in its infancy and therefore there are a number of issues that are unresolved in respect of the use of the data for mapping. At the time of writing this paper, only one successful launch of a high resolution sensor has been possible from three attempts. As well, since the systems are based on commercial ventures, the pricing of the data is based on a cost-recovery regime. The data is therefore relatively expensive and may not be affordable by developing countries.

Studies carried out to test the suitability of the data show that it should be suitable for mapping of peri-urban regions of cities as well as less densely populated areas, rather than inner city areas. It is likely that many countries will continue to base their mapping on aerial photography rather than the high resolution satellite data, since it has the flexibility of choice of scale to suit the purposes of the mapping project, time of photography, weather conditions etc.

A further issue is that the complete geometric characteristics of the image acquisition system, referred to as the geometric model of the data, will not be made available to the data users by the Space Imaging. This has the potential to affect the ultimate accuracy of information derived from the data, but the influences of these effects will depend of the purposes for which the data is to be used. To achieve the maximum accuracy from the data, it is believed that the geometric model will be required.

Airborne Systems

Film camera based systems will continue to be a major source of image data for mapping. However, aerial film camera systems have advanced significantly over recent years, especially in respect of the determination of camera exterior orientations. With the installation of both GPS and IMU on the camera, camera tilts and positions can me determined during flight. This has substantially reduced the need for field located ground control points, and hence significantly improved the economy of topographic mapping.

In parallel with the development of satellite systems, is the development of digital airborne systems. The ultimate intention is to replace the existing film based systems with digital systems. The advantage of the digital systems is that the data acquired is more flexible than that acquired by film based systems, and will be directly usable in digital photogrammetric systems. These systems will be available in 2001, but their cost is likely to be high until the development costs can be written off. It

is therefore clear that the data used for topographic mapping will involve film based systems, digitized by film scanning systems and used in the new generation digital photogrammetric plotters.

SENSORS FOR ELEVATION DETERMINATION

Environment monitoring and assessment will increasingly require elevations as a component for analysis in GIS. The accuracy of the elevations will also impact on the quality of this analysis. Over recent years, greater accuracy elevation information has been requested for environmental assessment and monitoring, especially in environmentally sensitive and flat areas. In the past, derivation of elevations has been an expensive process, since it has involved a manual operation. There are number of new developments that are now available for rapid determination of elevation, based both on aerial and satellite systems.

The traditional photogrammetric optical approach has now been replaced by the digital photogrammetric systems, which enable the acquisition of elevations automatically by image processing, called 'image matching'. This system is rapid and accurate, provided the terrain is not covered by dense vegetation. Usually assistance from an operator is required to correct the erroneous elevations. The process does require a significant level of training for the users to be efficient in the use if these systems.

Satellite Systems

New optical sensors dedicated to elevation extraction using fixed forward and aft camera systems, such as the high resolution systems described above, enable the acquisition of overlapping images that are available for the determination of elevations. Elevations can be determined from these systems with accuracies of 2 meters and better.

Interferometric SAR opens up new possibilities for global determination of digital elevation models from existing SAR data or from new missions. For interferometric SAR, the system involves the emission of radar data from one antenna and the acquisition of the reflected data on two antennas, or the system can also be based on the two separate passes of the satellite on two separate days, as is the

case with the ERS1/2 tandem mission. The Shuttle Radar Topographic Mission (SRTM) in February 2000 acquired data that will led to the determination of elevation over the Earth's surface from -54° to 60° in 9 days, with 30 meters spacing and accuracy approximately 10 meters. This data may be an important data set for the future for developing countries, although the processing will take 2 years to complete.

Airborne Systems

While some organizations will continue to extract elevation from aerial photography using optical instruments, the recently developed technologies for the automatic extraction of elevation from overlapping aerial photographs will become a major source of elevation data for mapping in future. It is expected that improvements will occur in the software design to overcome difficulties of extracting elevations over areas covered by trees and buildings.

Terrain laser scan systems is a recently developed technology that has now reached an operational stage. These systems involve a laser mounted in an aircraft that scans the terrain at right angles to the direction of flight. Measurement of the time take to receive the reflected signal from the terrain will enable the determination of high precision elevations. The system is a rapid terrain mapping that also penetrates thick vegetation. Hence it is a very efficient system for mapping, but requires large areas to ensure that it is economical. A number of systems are now on the market for terrain laser scanning and, while expensive to deploy, can lead to very economical mapping for large areas.

Multisensor data acquisition systems, such as camera and laser scanning are increasingly being used and require modification/extension of existing algorithms and procedures to effectively merge (fuse) multisensor data. At the same time, multispectral and even hyperspectral data have become available for other applications than traditional remote sensing, for example mapping urban areas. This greatly facilitates the automatic recognition and extraction of objects, such as buildings and roads.

MAPPING METHODS

For medium and large scale mapping photogrammetric equipment has now reached the digital instrumentation stage. The analytical plotter technology that existed in the 1970s and 1980s is now being replaced by the digital photogrammetric systems. While it can be expected that analytical

optical plotter systems will be available for some time, most of these systems are likely to be replaced by digital systems within 10 years. This has an impact on developing countries, since training in the use of the new technologies will be required before they can be efficiently implemented. Since the normal product derived from the digital photogrammetric systems is an ortho-image, an image with corrected geometry, there is a change in trends in the preferred mapping product, from line maps to ortho-images. The advantage of the image map is that it contains the full features of the original image, and hence is an important layer for a GIS.

An important development in digital data acquisition is the ability to fusion of data to produce useful information by processing within photogrammetric digital systems and integration into GIS. This involved several focal points, which included algorithms for feature extraction which could be incorporated in systems for automatic registration and data fusion. Semi automatic procedures are currently found in commercial systems to speed up the information extraction process, but increasing levels of automation will be used in these systems in future.

With the need to interchange data between software and hardware systems, there is a substantial need for transfer standards for both image and vector data. ISPRS is working with ISO and OGC to develop appropriate standards. They will be important for any organization that is using digital data for the mapping and GIS. Training will be an important issue to consider in the application of these standards.

ISSUES AFFECTING DEVELOPING COUNTRIES

The trends in technologies for mapping and GIS data collection towards digital data collection and will provide developing countries with new methods, that will have their advantages and disadvantages. The new technologies will lead to more rapid acquisition of terrain data, but the technologies will be expensive to acquire and they will require new levels of education and training.

For example, the new sources of image data, such as those from the high resolution satellites will be expensive to acquire and indeed, may prove out of the reach of most developing countries. The digital aerial cameras being developed will also be very expensive to acquire until their costs of development have been written-off. Terrain laser scan systems will be of great advantage to developing countries, since they acquire elevations accurately and rapidly. However, these systems

require special expertise to operate and hence surveys with them are likely to be undertaken by agencies at least in the short term.

The application of the new digital photogrammetric equipment for data acquisition requires new education and training of existing staff on their operation. Experiences in developing countries are that there is a considerable level of training required before these systems become operational. Similar periods will be required for developing countries to gain expertise in their use.

Technology transfer, maintenance of equipment and their regular replacement by upgrades will also be an issue, when this equipment is introduced into a mapping organization.

There will be significant long term benefits to the introduction of the new technologies into developing countries, since new data will be available and mapping from it will be more rapid and accurate. However, until the funding is available to purchase these systems and adequate training of personnel in their use is available, developing countries will have difficulties in taking advantage of these new technologies.